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Standard Specification for Copper, Copper Alloy, and Copper-Clad Stainless Steel Sheet and Strip for Electrical Cable Shielding¹

This standard is issued under the fixed designation B 694; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers selected copper, copper alloy, and copper-clad stainless steel materials, sheet and strip, in various thicknesses, for use as electrostatic or electromagnetic shielding for insulated power, control, instrumentation, and communication cables.

NOTE 1—See Specification B 736, for related standards for aluminum-based shielding materials.

1.2 The materials covered are the following:

Copper or Copper Alloy UNS No. ⁴	Type of Material
C11000	copper
C19400	copper-iron alloy
C22000	commercial bronze
C66400	copper-zinc-iron-cobalt alloy
C66410	copper-zinc-iron alloy
C71000	cupro-nickel 20 %
	copper-clad steel ^{1b}

⁴ The UNS system for copper and copper alloys (see Practice E 527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix "C" and a suffix "00." The suffix can be used to accommodate composition variations of the base alloy.

^{1b} Cladding ratio must be specified. (See 3.1, 7.5, 13.5, and Appendix X3.)

1.3 The values stated in inch-pound units are to be regarded as standard. SI values in parentheses are for information only.

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.1.1 ASTM Standards:

- A 176 Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip²
- B 152 Specification for Copper Sheet, Strip, Plate, and Rolled Bar³
- B 193 Test Method for Resistivity of Electrical Conductor Materials⁴
- B 248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar³

¹ This specification is under the jurisdiction of ASTM Committee B-5 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet, and Strip.

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² Annual Book of ASTM Standards, Vol 01.03.

³ Annual Book of ASTM Standards, Vol 02.01.

⁴ Annual Book of ASTM Standards, Vols 02.01 and 02.03.

B 601 Practice for Temper Designations for Copper and Copper Alloys—Wrought and Cast³

E 527 Practice for Numbering Metals and Alloys (UNS)⁵

B 736 Specification for Aluminum, Aluminum Alloy and Aluminum-Clad Steel Cable Shielding Stock⁶

3. Definition

3.1 *cladding ratio*—ratio by percent thickness of the component layers, for example, 20/60/20.

4. Ordering Information

4.1 Orders for material under this specification should include the following information:

- 4.1.1 Quantity: total for each item, pounds (or kilograms),
- 4.1.2 Name of material: cable shielding (or "cable wrap"),
- 4.1.3 Form of material: strip,
- 4.1.4 Type of material: copper, commercial bronze, etc. (see 1.2),
- 4.1.5 Alloy number when appropriate (see 1.2),
- 4.1.6 Temper (see Section 8),
- 4.1.7 Dimensions: thickness and width (see Section 13),
- 4.1.8 How furnished: coils (rolls), traverse wound on reels or spools, etc.,
- 4.1.9 Whether the resistivity test is required for any item (Section 12),
- 4.1.10 Coil dimension: inner or outer coil diameter limitation, or both, if required,
- 4.1.11 Weight of coils: coil weights or coil size limitations, if required,
- 4.1.12 Cladding ratio when appropriate (see 7.5),
- 4.1.13 Certification, if required,
- 4.1.14 Mill test report, if required,
- 4.1.15 Specification designation and year of issue, and
- 4.1.16 Special tests or exceptions, if any.

5. General Requirements

5.1 Material furnished to this specification shall conform to the applicable requirements of the current edition of Specification B 248.

6. Materials and Manufacture

6.1 The material shall be of such quality that it conforms to the properties and characteristics prescribed in this specification.

6.2 Cladding metals as appropriate may be bonded to the specified base metal by any method that will produce a clad

⁵ Annual Book of ASTM Standards, Vols 01.01 and 02.01.

⁶ Annual Book of ASTM Standards, Vol 02.02.

TABLE 1 Chemical Requirements

Element	Composition, %						Copper Coating of Bimetallic Copper or Copper Alloy UNS No.	
	Copper or Copper Alloy UNS No.						C10300	C12200
	C11000	C19400	C22000	C66400	C66410	C71000		
Copper (incl silver)	99.90 min	97.0 min	89.00–91.0	remainder	remainder	74.0 min	99.95 min ^A	99.9 min
Iron	...	2.1–2.6	0.05 max	1.3–1.7	1.8–2.3	1.0 max	...	...
Lead, max	...	0.03	0.05	0.015	0.015	0.05	...	...
Tin	...	...	...	0.05 max	0.05 max	...	...	...
Zinc	...	0.05–0.20	remainder	11.0–12.0	11.0–12.0	1.0 max	...	...
Nickel (incl cobalt)	...	...	...	...	0.05 max	19.0–23.0	...	...
Manganese	...	...	...	...	0.05 max	1.0 max	...	...
Phosphorus	...	0.015–0.15	...	...	0.02 max	...	0.001–0.005	0.015–0.040
Cobalt	...	...	...	0.30–0.7	...	...	...	...
Silver	...	...	...	...	0.05 max	...	...	...
Silicon	...	...	...	...	0.05 max	...	...	...
Aluminum	...	...	...	...	0.05 max	...	...	...

^A Copper + silver + phosphorus, min.

material that will conform to this specification.

7. Chemical Composition

7.1 Homogeneous copper-bearing materials shall conform to the chemical requirements prescribed in Table 1.

7.2 Copper cladding shall be, unless otherwise specified, a copper conforming in chemical composition to that covered by Specification B 152, Copper UNS No. C10300 (Table 1). By agreement between manufacturer or supplier and purchaser, Copper UNS No. C12200 (Table 1) may be supplied.

7.3 The specification limits do not preclude the presence of other elements. Limits for unnamed elements may be established by agreement between manufacturer or supplier and purchaser.

7.4 For copper alloys in Table 1, copper may be taken as the difference between all the elements analyzed and 100 %.

7.4.1 *Alloys C19400 and C22000*—When all the elements in Table 1 are analyzed, their sum shall be 99.8 % min.

7.4.2 *Alloys C66400, C66410, and C71000*—When all the elements in Table 1 are analyzed, their sum shall be 99.5 % min.

7.5 Clad cores shall be a stainless steel conforming in chemical composition to any of those covered by Specification A 176. Unless otherwise specified, stainless steel in accordance with UNS No. S43000 (Type 430) shall be supplied.

7.6 Unless otherwise stated (4.1.12), the cladding ratio shall be one of the standard ratios listed in Tables 2 and X2.1, and shall be expressed as XX/XX/XX, copper/stainless steel/copper.

8. Temper

8.1 Materials furnished to this specification shall be annealed or cold-rolled to the temper specified (4.1.6). The standard designations as defined in Practice B 601 are shown. Standard tempers commonly available are listed in Table 2; special or nonstandard tempers are subject to negotiation between manufacturer or supplier and purchaser.

9. Mechanical Properties of Cold-Rolled and Annealed Tempers

9.1 The tension test shall be the standard test for all

tempers of cold rolled strip and for annealed Copper UNS No. C11000 and Copper Alloy UNS Nos. C19400, C66400, and C66410 and acceptance or rejection shall depend only on the tensile properties which shall conform to the applicable requirements prescribed in Table 2. Tension test specimens shall be taken so the longitudinal axis of such specimens is parallel to the direction of rolling.

9.2 The mechanical properties of copper-clad steel material in tempers other than fully annealed and with cladding ratios other than listed in Tables 2 and X3.1 shall be as agreed upon between purchaser and supplier.

10. Grain Size Requirements of Annealed Tempers

10.1 Grain size shall be the standard test for annealed strip of Copper Alloy UNS Nos. C22000 and C71000, and acceptance or rejection shall depend only on the grain size. The average grain size of each of two samples of annealed material, as determined on a plane parallel to the surface of the strip, shall be within the limits prescribed in Table 3.

10.2 Although no minimum grain size is prescribed for fully annealed copper-clad steel material, it shall be fully recrystallized in both cladding and core.

11. Rockwell Hardness

11.1 Since Rockwell hardness tests offer a quick and convenient method of checking the conformity of the material to the requirements for tensile strength or grain size, the approximate Rockwell hardness values are given in Table 2 for general information and assistance in testing but shall not be used as a basis for rejection. For copper-clad material, copper should be etched off with suitable reagent prior to testing the steel.

12. Electrical Conductivity

12.1 When specified in the order, the electrical conductivity determined on annealed samples shall have the following value when tested at a temperature of 20°C (68°F):

Material or UNS No.	Electrical Conductivity, min, % IACS
C11000	100.00
C19400	60
C22000	40
C66400	30
C66410	30

TABLE 2 Tensile Strength Requirements and Approximate Hardness Values for Shielding Materials in Commonly Ordered Tempers

Description		Temper Designation		Tensile Strength, ksi ^A (MPa ^B)		Approximate Rockwell Hardness ^D		
Copper or Copper Alloy UNS No.	Type of Material	Standard	Former	Min	Max	Other Scales Thicknesses >0.020 in.		Superficial 30T Thicknesses >0.012 in.
C11000	Copper	H00	<i>Cold-Rolled Tempers:</i> eighth hard	32 (220)	40 (275)	F	54–82	up to 49
		H01	quarter hard	34 (235)	42 (290)	F	60–84	18–51
		H02	half hard	37 (255)	46 (315)	F	77–89	43–57
		O61	<i>Annealed Tempers:</i> annealed	...	34 (235)	...	...	...
		O61	<i>Annealed Tempers:</i> annealed ^C	45 (310)	55 (380)	...	...	...
C19400	Copper-iron alloy	O50	light annealed ^C	50 (345)	60 (415)	...	...	...
		H02	half hard	53 (365)	63 (435)	B	49–69	52–63
			<i>Cold-Rolled Tempers:</i> quarter hard	40 (275)	50 (345)	B	27–52	38–53
C22000	Commercial bronze	H02	half hard	47 (325)	57 (395)	B	50–63	52–61
		O81	<i>Annealed Tempers:</i> quarter hard	39 (270)	46 (315)	...	...	...
		O60	<i>Annealed Temper:</i> soft ^C	53 (365)	60 (415)	...	...	...
		O60	soft ^C	53 (365)	60 (415)	...	...	...
C66410	Copper-zinc- iron alloy	O60	soft ^C	53 (365)	60 (415)	...	...	...
C71000	Cupro-nickel 20 %	H01	<i>Cold-Rolled Tempers:</i> quarter hard	47 (325)	63 (435)	B	45–72	46–65
		H02	half hard	56 (385)	70 (485)	B	64–78	59–69
		OS035	<i>Annealed Tempers:</i> 0.035-mm grain size	52 (355)		B	18–35	28–40
		OS015	0.015-mm grain size	53 (365)		B	35–88	40–58
Copper-Clad Steel								
Cladding Ratio	Total Thickness in. (mm)							
20/60/20	0.004 (0.10)	O61	<i>Annealed Tempers</i> annealed ^C	51 (350)		15T	89 max	...
16/68/16	0.005 (0.13)	O61	annealed ^C	55 (380)	68 (470)	15T	89 max	...
33.3/33.3/ 33.3	0.006 (0.15)	O61	annealed ^C	44 (305)		15T	89 max	...

^A ksi = 1000 psi.^B See Appendix X4.^C There is no grain size requirement but all annealed metal shall be fully recrystallized.^D Rockwell values normally apply as follows: The B and F scales apply to metal 0.020 to 0.036 in. (0.5 to 0.91 mm) in thickness. The Superficial 30-T scale applies to metal 0.012 to 0.028 in. (0.30 to 0.71 mm) in thickness.

Material or UNS No.

Electrical Conductivity,
min, % IACS

C71000

Copper-clad steel

6

A

TABLE 3 Grain Size Requirements for Annealed Material

Copper Alloy UNS No.	Temper Designation		Average Grain Size, mm		
	Standard	Former	Nominal	Min	Max
C22000	OS010		0.010	^A	0.020
C71000	OS015	annealed	0.015	^A	0.025

^A Although no minimum grain size is required, this material must be fully recrystallized.

12.2 The electrical resistivity of the material shall be determined in accordance with Test Method B 193; the conductivity shall be calculated in accordance with Explanatory Notes 3 and 4 of Test Method B 193.

13. Dimensions and Permissible Variations

13.1 *General*—For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimension may be cause for rejection.

13.2 *Thickness*—The standard method of specifying thickness shall be in decimal fractions of an inch. For material 0.021 in. (0.53 mm) and under in thickness, it is recommended that the nominal thicknesses be stated not

closer than the nearest half-thousandth. (For example, specify 0.006 or 0.0065 in. (0.15 or 0.165 mm), but not 0.0063 in. (0.160 mm).) A list of preferred thicknesses is shown in Appendix X1. The thickness tolerance shall be those shown in Tables 4(a) and 4(b).

13.3 *Width*—The width tolerances shall be those required by Specification B 248, Paragraph 5.3, unless otherwise stated in the purchase order.

13.4 *Straightness*—The straightness tolerances shall be those required by Specification B 248, paragraph 5.5, unless otherwise stated in the purchase order.

13.5 *Cladding Ratio*—Cladding ratios shall be within $\pm 10\%$ of nominal; test method shall be metallurgical

TABLE 4(a) Thickness Tolerances

Material	Thickness, in. (mm)	Tolerance, plus and minus in. (mm)	
		12 in. (305 mm) and under in Width	Over 12 in. (305 mm) and up to 24 in. (610 mm) in width
Copper and copper alloys	0.004 (0.102) and under	0.0003 (0.0076)	0.0006 (0.015)
	Over 0.004 to 0.005 (0.127), incl	0.0004 (0.010)	0.0008 (0.020)
	Over 0.005 to 0.009 (0.229), incl	0.0005 (0.013)	0.001 (0.025)
	Over 0.009 to 0.013 (0.330), incl	0.0008 (0.020)	0.0015 (0.038)
Copper-clad steel	0.004 (0.102) and under		
	Over 0.004 to 0.006 (0.152), incl	0.0005 (0.013)	
	Over 0.006 to 0.009 (0.229), incl	0.0006 (0.015)	

microsection of at least three samples per lot. See Appendix X3 for preferred cladding ratios.

14. Workmanship, Finish, and Appearance

14.1 All material shall be uniform in quality and condition, sound and free of internal and external defects of a

nature that interferes with normal fabrication or the performance of the cable shielding. It shall be well-cleaned and free of dirt. A superficial film of residual light lubricant is permissible, unless otherwise specified.

14.2 Copper-clad material shall be free of defects including unbond or delamination of a nature that interferes with normal commercial operations.

TABLE 4(b) Width Tolerances for Slit Metal and Slit Metal with Rolled Edges

(Applicable to all materials listed in 1.2)

Width, in. (mm)	Width Tolerances, ^A plus and minus	
	For All Thicknesses	
	in.	mm
2 (50.8) and under	0.005	0.13
Over 2 to 12 (50.8 to 305), incl	0.008	0.20
Over 12 to 24 (305 to 610), incl	0.015	0.38

^A If tolerances are specified as all plus or all minus, double the values given.

APPENDIXES

(Nonmandatory Information)

X1. EXPLANATORY NOTE—CABLE SHIELDING

X1.1 Cable shielding or "cable wrap" is normally used by manufacturers of electrical insulated wire and cable in strips of various widths. The material is wrapped around an insulated wire or group of wires, and may be applied over an intervening layer of wrapping material or over a jacket. The material may be applied in various configurations depending upon the requirements of the finished cable:

X1.1.1 *Helical wrap*—overlapped, butted, or gapped.

X1.1.2 *Longitudinal application*—corrugated or smooth, overlapped, butted, gapped, or welded/soldered.

X1.2 The selection of the particular material and of the thickness of the material to be used is dependent largely

upon the specification requirements for the finished wire or cable. Military and Federal Specifications, Rural Electrification Administration (REA) specifications, ICEA (Insulated Cable Engineers Association) specifications among others, typically apply.

X1.3 Electrical conductivity of the material is an important characteristic considered in the selection process, and is affected by the material, its thickness, and the method of application. Corrosion resistance is important for various environments. Physical strength requirements may include such features as resistance to tensile stress, resistance to bending stress (including repeated bending), resistance to gopher attack, etc.

X2. PREFERRED THICKNESSES

X2.1 It is recommended that wherever possible, material listed in Table X2.1. purchased to this specification be ordered in a thickness as

TABLE X2.1 Preferred Thickness, Nominal

Material or UNS No.	Thickness, in. (mm)
C11000	0.005 (0.13)
	0.010 (0.25)
C19400	0.006 (0.15)
	0.007 (0.18)
C22000	0.005 (0.13)
	0.007 (0.18)
	0.010 (0.25)
C66400	0.0055 (0.14)
C66410	0.0055 (0.14)
C71000	0.005 (0.13)
Copper-clad steel	0.004 (0.10) ^A
	0.005 (0.13) ^A
	0.006 (0.15) ^A

^A Total thickness of strip. See Table X3.1 for preferred cladding ratio.

X3. PREFERRED CLADDING RATIOS FOR COPPER-CLAD STEEL

X3.1 It is recommended that wherever possible, material cladding ratios as listed in Table X3.1. Conductivity for these purchased to this specification be ordered in thicknesses and recommended materials is indicated.

TABLE X3.1 Preferred Cladding Ratios—Copper-Clad Steel

Nominal Total Thickness of Strip		Cladding Ratio, Cu/ss/Cu	Nominal Thickness, in. (mm)			Conductivity, % IACS	
in.	mm		Copper	Steel	Copper	nominal	min
0.004	0.10	20/60/20	0.0008 (0.02)	0.0024 (0.06)	0.0008 (0.02)	32	30
0.005	0.13	16/68/16	0.0008 (0.02)	0.0034 (0.09)	0.0008 (0.02)	30	28
0.006	0.15	33.3/33.3/33.3	0.002 (0.05)	0.002 (0.05)	0.002 (0.05)	61	60

X4. METRIC EQUIVALENTS

X4.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or

stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$ the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

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